

Making Connections: Service-Learning in Introductory Cell and Molecular Biology [†]

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This report describes service-learning in a first-year majors biology course in which students serve throughout the semester with community partners for an average of 25 hours/student. All of the partnerships are based on providing engaging hands-on biology activities for youth in underserved urban areas surrounding the campus. Students in the course have designed new lessons and activities, supported biology labs, mentored younger students, and facilitated afterschool science clubs. Throughout the course, integration between the students' service experience in the community and their learning in the course is emphasized. This is accomplished in multiple ways including class discussion, group activities, feedback from the instructor and teaching assistant, and weekly blogs. A three-year average of anonymous university-wide course evaluations suggested that students in this service-learning course considered their biology course to be highly rigorous. In both blogs and anonymous surveys students reported that their service and its integration with the course not only advanced their professional skills and sense of community engagement, but also enhanced their learning in biology.

INTRODUCTION

Service-Learning (S-L) is a pedagogy that aims to enhance student classroom experiences and community engagement through targeted service that meets community-identified needs and reflection activities that integrate that service back into the academic framework of the course (5). Service-learning, like undergraduate research, is one of ten high-impact practices known to increase student retention and engagement (11). Although service-learning has become very widespread in undergraduate education, applications in the life sciences are rare. This may seem surprising in light of the fact that numerous studies have documented benefits in discipline-based learning for students engaged in service-learning experiences, reviewed in Felton and Clayton (9), as well as development of personal and professional skills and increased civic-mindedness (11). Two recent meta-analyses have also concluded that service-learning experience increases learning outcomes (14, 15).

Published peer-reviewed articles are mostly focused on service-learning as a general pedagogical tool or on the application of service-learning in the context of teacher education courses or health professional (e.g., nursing) studies. Within the natural sciences, applications of service-learning are

most often reported in the environmental sciences, while references to biology at the cellular level are rare. Larios-Sanz and colleagues (12) described the implementation of a medical microbiology service-learning project in which students volunteered in clinics in underserved areas and then produced educational materials for patients based on their observations. The service-learning was well received by students and community partners, but the majority of students did not believe that their learning in the course was enhanced by the experience. The authors postulated that this result could, in part, be due to a misinterpretation of the survey question by respondents, but they also believed that increased integration of the service component into the course content was probably warranted. Indeed, in a large-scale study of service-learning courses across 30 disciplines, Levesque-Bristol and colleagues (13) concluded that the extent of positive service-learning outcome is largely dependent on how the service-learning is implemented in the course. The most important factors in that study were the type of service and the amount and type of in-class discussion and other reflection activities.

This report describes a service-learning model implemented in an introductory cell and molecular biology course, Inquiries in Cell and Molecular Biology, for a mixed group of life science majors over a three-year period. Students reported gains in biology knowledge and skills as a direct result of the service-learning component of the class, while also reporting higher levels of course rigor and learning for the course overall than reported by students in other biology courses without service-learning. For the service component, first-year biology students were placed in K-12

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educational settings, primarily after-school programs, where they served throughout the entire semester. Students were asked to integrate their work in the community with overarching biological principles discussed in class on a weekly basis. This presented a challenging task, as students were working at a much more basic level of biology understanding in their service than in the class. However, the requirement to search for and explicitly describe a link between the two provided a mechanism to reinforce and expand core biological knowledge.

Intended audience

This service-learning activity was implemented in a course for first-year students majoring in the biological sciences who had earned advanced placement (AP) credit, but it could easily be adapted for majors taking a traditional introductory course or for non-majors. The course itself was designed as a one-semester bridge for majors entering with AP credit for Principles of Biology (having earned a score of 4 or 5 on the AP biology exam). Students in this course did not take a traditional introductory biology survey course, but progressed directly into intermediate biology courses after this semester.

Learning time

Service-learning was a required, integrated, semester-long component of the course. Students were required to serve for a minimum of two hours/week, but individual student service ranged from two to five hours/week. Service-learning role assignments were made the second week of the semester; on-site orientations were held by most partner organizations by the third week; and students began serving after orientation and continued until the last week of classes. The service component was integrated into the course via weekly blogs and class discussions.

Prerequisite student knowledge

Students in this class had taken AP biology in high school and many had some volunteer experience, but their biology backgrounds were quite varied and the service component of the course was unlike their previous volunteer experiences. The service-learning described here could be carried out in the same way for students without AP biology credit or previous college biology coursework. Because the community partnerships were all focused on the K–12 population, mostly middle school, the biological topics and activities were at a basic level that did not require extensive background knowledge for the service-learners.

Learning objectives

1. Consolidate and reinforce basic biology knowledge
2. Apply course concepts and skills

3. Develop professional skills
4. Engage with, learn from, and contribute to the community

PROCEDURE

Student instructions

Students participated in a workshop at the beginning of the semester that explained the goals and process for service-learning, introduced the neighboring communities around campus, and described the community partners and available service roles (Appendix I). Although the partnerships and roles varied, in every case the service-learners were working either directly or indirectly to provide engaging, hands-on biology-related activities to area youth (see Table I for description of community partnership types). Students were given a service placement handout listing each community partner, contact information, and organizational mission. The handout detailed the service opportunities, duties and responsibilities of service-learners, and logistics (e.g., dates and times of service), required or suggested skills, number of students needed, and placement requirements such as completion of a volunteer application, on-site orientation, training, and criminal background checks (Appendix 2). Service-learning roles were assigned based on community partner needs and student preferences (see Appendix 3 for student preference form). After students were assigned to a community partner, they participated in on-line and/or on-site orientations and training organized and run by the community partners. At each partner site, a staff person was designated to serve as the primary contact and supervisor of the service-learners. The instructor was not involved in direct supervision of student service on-site.

Once service commenced, students integrated their service work with the course primarily through weekly

TABLE I.
Service-learning partnerships.

Partner Organization	Service Type	Student Role
Community Center	Direct	Design/deliver hands-on biology activities
After-School Enrichment	Direct	Facilitate established science curriculum
After-School Enrichment	Project	Design or revise science curriculum
STEM Outreach Program	Direct	Assist in AP biology laboratories
STEM Outreach Program	Project	Design outreach activities

AP, advanced placement.

blogs. Students were required to write a blog entry and to comment on at least one other student's blog in a substantive way each week. Students wrote 10 blogs over the course of the semester, commencing after the beginning of service and ending the last week of class (see Table 2 for the blog grading rubric). Students were instructed to avoid using the blog as a journal in which they simply reported on their service experiences and their personal reactions to those experiences. Instead, they were asked to make clear what they were learning through their service commitment and how that related to the concepts that they were learning through traditional class activities (assigned readings, lectures, discussions, in-class activities, etc.). Table 3 gives examples of activities that students designed and/or carried out in their service that helped to reinforce the major concepts and disciplinary practices that they were expected to learn in the course. These core concepts and practices are used to structure the course (4) based on proposals put forth by the American Association for the Advancement of Science (1).

Grades were not based directly on service (e.g., number of hours served), but on the assignments that integrated the service into the practice of the course as well as active participation in service-related responsibilities. The blogs represented 15% of the total course grade. Traditional assessments (quizzes, exams, a research project, and attendance and participation) accounted for the remainder of the grade. Feedback from community supervisors on student attendance and service work was sought early in the service period so that issues could be resolved proactively. The student's satisfactory completion of service was incorporated into the attendance and participation component of the course grade.

Faculty instructions

Instructors need to make connections with community organizations and match their needs to the learning goals of the course, keeping in mind logistical considerations such as student schedules and experience level. These partnerships are best developed and maintained when courses continue or repeat from fall to spring terms. However, we were able to run this course just once a year and maintain and recruit partnerships through the assistance of the Service-Learning Program within the Center of Community Service. Even at institutions without formalized service-learning, established relationships that could form the basis of service-learning partnerships likely exist. Ideally, partnerships should be developed several months ahead of time to ensure that there will be sufficient service roles for the students when the course begins and that community needs will be met.

We partnered both with school-based enrichment programs and community centers, in many cases building on partnerships that already existed between the University and the community organization. For example, many students at the University volunteer at the local Boys and Girls Club. This relationship led to discussions with youth workers about what types of enrichment activities they would like to be able to implement. Stimulating youth interest in science and technology fields was an unfulfilled need at the club that our class was able to fill via service-learning. The students who partnered with the Boys and Girls Club were divided into groups of three students that rotated responsibilities on a three week basis: one week of observation and planning, one week of further planning and revision of activities, and one week leading the planned activities at the club.

TABLE 2.
Service-learning blog grading rubric.

Performance Level → Parameter ↓	Basic	Intermediate	Advanced
Integration	Addresses biology topic from S-L work, but does not demonstrate how that topic relates to coursework	Addresses cell/molecular biology topic from S-L work and relates it to at least one concept from class	Addresses cell/molecular biology topic from S-L work and clearly relates it to multiple course concepts, linking them together <i>explicitly</i>
Scientific Content & Accuracy	Several small scientific errors and/or points of possible confusion; sources are cited when necessary	No scientific errors; may be a minor source of confusion; credible sources are used and cited appropriately	No errors; very clear descriptions, unlikely to be any points of confusion; credible sources, appropriate citations, S-L learning put in the context of recent advances in the larger field
Writing	Writing is clear and descriptive, contains few if any grammatical and spelling errors; submitted on time	Writing is clear, free of grammatical and spelling errors, is largely descriptive but includes some analysis; submitted on time	Writing is clear and detailed, free of grammatical and spelling errors, and demonstrates both description and analysis; there is no extraneous material; submitted on time

TABLE 3.
Connecting service activities to course content.

Core Course Concept or Practice ^a	Example of Reinforcing Service Activity
Evolution	Natural selection game
Cellular Structure & Function	Mosaic membrane art
Genetic Information	UV mutagenesis experiment
Energy & Pathways	Yeast glycolysis demonstration
Systems	Immune system computer game
Process of Science	Middle school science fair project development
Quantitative Reasoning	Experiment data analysis and visualization
Modeling & Simulation	3-Dimensional DNA models
Interdisciplinary Practice	Bioremediation activity
Communication & Collaboration	Project development teams/community feedback
Science & Society	Cancer prevention public service announcement

^aBased on the American Association for the Advancement of Science Report, Vision and Change in Undergraduate Biology Education: A Call to Action (1, 4).

In other cases we were able to help a community organization maintain or expand a biology program that already existed. For example, Science Club for Girls is a well-established science enrichment program that is often looking for scientists or science students to serve as mentors for nine-week after-school programs. Several inquiries students filled that direct-service role. Other students worked in small groups of 3–4 to design new activities for clubs or revise and improve pre-existing lessons.

A trained undergraduate served as the Service-Learning Teaching Assistant (S-L TA). The S-L TA helped maintain relationships with community partners throughout the semester and kept service-learners on-task. If an S-L TA is not available, the instructor needs to be in regular contact with community partners to ensure that the partnerships are working for all parties. A primary contact at each community organization (often the volunteer coordinator) supervised the students on-site or, if they were involved in off-site curriculum development projects, gave feedback on student products. The instructor did not supervise or coordinate the service, but instead focused on helping students to integrate what they learned in the classroom with their hands-on learning outside.

Students reported the best outcomes when the service role aligned well with the course and when expectations were very clear. Direct service roles were easier to manage

than indirect projects such as writing new lessons for an after-school program, and generally were better received by the students. This is consistent with the findings of Levesque-Bristol and colleagues (13), who found that students who had direct interactions with the people they were serving rated their learning environment as significantly more positive than did students involved in indirect service.

Students providing direct service on a weekly basis were able to adapt quickly to the needs of the community partner and to target activities appropriately to the age group they were serving. However, students involved in projects to develop curriculum activities for a community partner to use in the future had trouble understanding what constituted a well-timed and engaging activity. Consequently, service-learners working on curriculum design projects are now required to visit the community partner at least once early in the semester to observe the program in action. The S-L TA met with these students weekly to review progress and the instructor reviewed draft materials as needed.

Explicit instructions were given for integration of service with course content in weekly blog assignments. This allowed students to make connections between their service activities and the course and receive timely feedback from the instructor. For this course, a blog tool included in the course management software package Blackboard was used to create the blog and set parameters such as whether anonymous posts are allowed and whether or not student entries will be graded. A rubric was also created with the blog tool, allowing the instructor to grade student entries directly with a grading scheme that can be seen by the students. The grade then appears automatically in the course management grade book. The instructor can also include feedback comments that are visible only to the individual student.

Suggestions for determining student learning

Weekly blogs provided formative assessment of student learning throughout the semester. Because the blog is a public dialog for the course, it allows immediate feedback from the instructor and from classmates. Students were encouraged to use the comment function to offer suggestions and pose questions (see Appendix 4 for example blogs and comments). This allowed learning that occurred within the context of one community partnership to be shared with students serving in other roles or with other partners. The blog assessment provided information on student misconceptions, topics that required further exploration, and skills that needed development (e.g., reference to credible sources). At the beginning of each week, the instructor spent about 15 minutes of class time leading a discussion of interesting topics, points of confusion, or logistical issues that arose in the students' writing from the previous week. Students' perceptions of learning gains were also assessed with formal end-of-semester surveys.

Safety issues

The safety issues surrounding the service component for the university students related to traveling and working in an urban environment. Students were advised about important safety precautions, such as traveling with other students, and asked to report any concerns throughout the semester to their TA and instructor. No problems occurred. There were also potential additional safety issues to be considered for students who were designing activities for youth. Students were required to clear materials and procedures with the instructor and the community partner before implementing activities. Informed Consent: this research has complied with all relevant federal guidelines and institutional policies.

DISCUSSION

Field testing

This service-learning activity was tested over a three-year period with a class size of approximately 40 students, for a total of 116 students. In each offering of the course, four to six community partners accepted the service-learners, who worked in pairs or small groups of three to five students. The needs identified by community partners were all in the area of science enrichment for youth in underserved urban areas. In the three years of the course reported here, students provided nearly 3000 hours of service and all partner organizations reported that the service-learners helped support the organizational mission.

Evidence of student learning

Because time devoted to service-learning may affect the amount of topical coverage possible in the course, it is important to consider course rigor. At the end of each semester students throughout the University complete a standardized electronic course evaluation. Likert question data from these anonymous surveys are reported to instructors as numerical values on a scale of 1 to 5, along with comparison data from other courses. Several questions on the survey address student perceptions of course rigor and learning. Figure 1 illustrates that students in this service-learning course reported a higher level of intellectual challenge, learning, and application of concepts than students in all biology courses (average for all undergraduate courses offered in the biology department in the same semester). The differences were significant at $p < 0.05$ in a Student's *t*-test for questions asking if students felt intellectually challenged (0.02) and had applied concepts (0.04), but not for the amount learned (0.06). While these surveys ask students about the course as a whole, rather than focusing on the service-learning component, the results do suggest that students felt that overall course rigor was high.

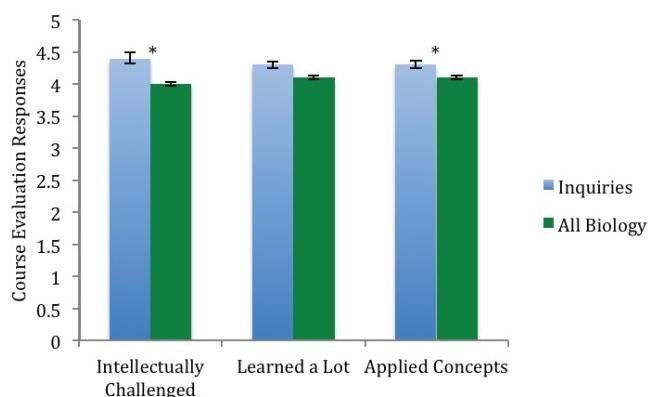


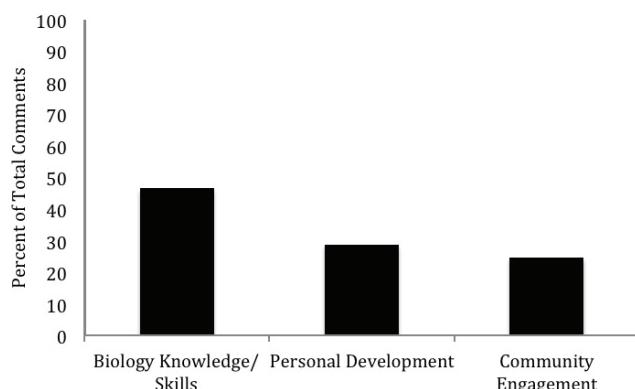
FIGURE 1. Results of standard university course evaluations comparing the service-learning course, Inquiries in Cell and Molecular Biology, to all undergraduate biology courses offered in the same semester. Average scores over a three-year period are reported. Error bars represent the standard error of the mean.

* Indicates differences significant at $p < 0.05$ in a Student's *t*-test. For 'learned a lot' the *p*-value was 0.06.

In the third offering of the course, students were asked to write a final summary of their service-learning experience (see Appendix 5 for examples). These responses were posted on the blog and were not anonymous. Qualitative analysis was performed on the summaries using grounded theory (3, 10), which is based on an iterative process of reading the text and extracting and categorizing textual themes. A number of software packages are available to help organize categories for qualitative analysis, but text can also be coded manually using spreadsheets or tables, as was done here (6). Figure 2 (A) shows that the most common theme mentioned by students in their summaries of service-learning experiences related to biology skills and knowledge, followed by personal development and then civic engagement. This is notable, as learning gains in areas outside of the academic discipline (e.g., professional skills and increased civic engagement) might be expected to predominate because students were working at a basic level of biology in their service to local youth. The fact that learning in biology was the dominant theme is consistent with several large studies of learning outcomes in service-learning courses (2, 14, 15) and is notable because very few science courses have been examined. In this course, students reported understanding fundamental biological concepts and learning how to apply those concepts to a range of biological problems as a result of their service-learning.

An analysis of minor themes in the biology knowledge and skills category (Fig. 2 (B)) showed that most students felt that they had increased their understanding of biological concepts through service-learning. Improved scientific skills and enhanced appreciation for the importance of biology were also reported. However, about 8% of the comments in this category expressed difficulty in or frustration with trying to find relevant links between the service and the study of

A – Major Themes



B – Minor Themes in Theme I: Biology Knowledge/Skill

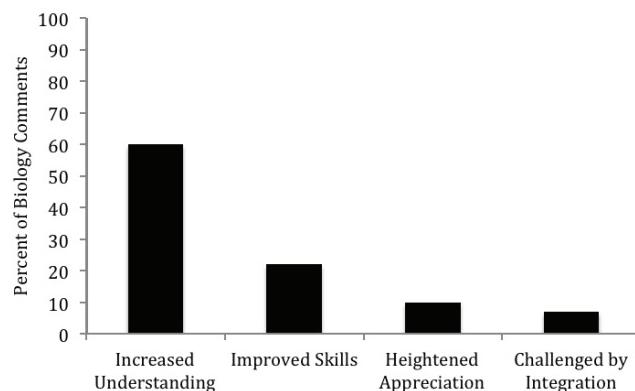


FIGURE 2. Qualitative analysis of students' summary blog text: percent of total comments. (A) Three major themes emerged from a grounded theory analysis of blog text: biology knowledge and skills, personal development, and community engagement. (B) Minor themes within the biology knowledge and skills category.

biology, meaning that 92% of the biology knowledge comments reported a perceived gain in knowledge from service-learning, while 8% of the comments highlighted challenges in finding regular links between service and biology knowledge. These comments often mentioned the different topics and/or levels in class versus service. However, the majority of students were able to make connections between the two based on overarching principles.

Because the summary blogs were not anonymous, they may have been impacted by students' desire to please the professor or classmates. Students also participated in an anonymous survey designed and administered to students in all service-learning courses by the University. This survey was administered at the end of each semester and focused exclusively on the service-learning component of the course. Additional course-specific questions were added each year the course was offered. A set of questions addressing the specific learning objectives of the service-learning component of the course was included in years two and three (responses are summarized in Table 4). Students reported that service-learning met the biology objectives very well and met the professional objectives very well or extremely well. Nearly three-quarters of students also felt that their

TABLE 4.

Student assessment of learning objectives for service-learning.

Objective	Survey Question	Responses (Mode in Bold)
1	Service-learning experience reinforced biology knowledge	1 = not at all 2 = minimally 3 = moderately well 4 = very well 5 = extremely well
1	Deepened understanding of biology fundamentals through service-learning	1 = not at all 2 = minimally 3 = moderately well 4 = very well 5 = extremely well
2	Applied molecular & evolutionary theory to a range of biology topics through service-learning	1 = not at all 2 = minimally 3 = moderately well 4 = very well 5 = extremely well
3	Service-learning enhanced development of professional skills	1 = strongly disagree 2 = disagree 3 = neutral 4 = agree 5 = strongly agree
3	Service-learning helped clarify professional goals/options	1 = strongly disagree 2 = disagree 3 = neutral 4 = agree 5 = strongly agree
4	As a result of service-learning, sense of connection to the community has	1 = increased 2 = decreased 3 = stayed the same

connection to the community had increased as a result of their service-learning experience. These student outcomes are noteworthy because they indicate that the intended biology goals were met and that students' perceived skills and civic attitudes had also changed. This is consistent with the service-learning literature (2, 7, 8, 14, 15).

Students were highly positive in their anonymous open response comments about how service-learning affected them. Some samples are included below.

Because we reviewed cell structure and function [in service-learning], as well as other basic processes on a biological level, my understanding of these fundamentals was deepened. I think this service-learning definitely helped me to polish up on these fundamentals and get a better understanding of them.

Integration was probably the best thing that came from this program. The ability to integrate what I learn in class to what I teach and vice versa has helped me appreciate the science so much more.

I think being able to recite what we learned in class and explain it in simpler terms [in service-learning] helped me to learn the most. I felt like you really need to thoroughly understand a topic in order to break it down into simpler bits and this course really enabled me to do that for myself and for my community partner.

The service-learning was effective in helping me understand the articles we read in class at a more basic level. There would always be a connection with what I was learning in class to what was being taught in the service-learning classroom. The service-learning helped me think back to the basics and helped me understand the topic in the classroom more easily. If there was something that was asked in the [service-learning] classroom that I didn't know I would look it up and try and find a credible source that would answer the questions for the next week.

This course helped me to connect my experiences in a biology class to real world applications and opened my eyes to the many paths that a degree in biology can take me down.

Writing blogs helped me think of how to relate class topics to the students' labs. I was more motivated to research links between our curriculum and their activities.

The service-learning helped me learn a lot because when you have to break down something scientific into terms that younger kids can understand, it shows if you really understand the material on the most basic level.

All of the measurements of learning reported here are based on student self-reports. Interestingly, a recent meta-analysis of service-learning studies observed no statistically significant difference between student self-reports of learning and independent measures of learning such as assignment and exam scores (15). The Inquiries in Biology students were overwhelmingly positive about their service-learning experience and felt that it had helped them to attain learning objectives for the course including enhanced understanding of biological principles.

Possible modifications

The course described here was focused on cell and molecular biology, which made the connections rather difficult for students to discern initially, especially in cases where they were working on activities for youth related to higher levels of biological organization, such as ecology or ocean science. However, the service-learning blog integration requirement forced them to dig deeper and discover that all biology has its foundation in cell and molecular processes. The service-learning approach used here could easily be adopted for use in introductory courses in

microbiology, evolutionary biology, ecology, etc. The key to success is twofold: 1) ensure that community partners have identified needs for your students to fill that align well with your course objectives and 2) require that students find and explicitly describe the connections between what they are teaching the youth and what they are learning in class. Some of the most profound learning occurred when students needed to independently research biological principles that they had thought they understood in order to explain them to children. This approach of learning by teaching worked very well in a course where students had earned advanced placement credit for their first-year biology course sequence, because their high school experiences varied and so did their knowledge gaps. However, this should apply equally well to students who do not have advanced placement credit.

SUPPLEMENTAL MATERIALS

- Appendix 1: Service-learning introductory workshop for students
- Appendix 2: Template for Community Partnership Form
- Appendix 3: Template for Student Preference Form
- Appendix 4: Example of weekly blog and associated comments
- Appendix 5: Examples of summary blogs

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